§11. Loss Cone Boundary Measurement Using Diagnostic Neutral Beam and Neutral Particle Analyzer in CHS

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A horizontally scannable diagnostic neutral beam (DNB) has been installed on the compact helical system (CHS) in order to study confinement of energetic ions with different pitch angle by varying injection angle. The DNB has been designed to provide energetic ions as a test particle source with 1) no heating to background plasma 2) small divergence angle. A charge-exchange (CX) neutral particle analyzer (NPA) is also scannable and varies the observation angle on the equatorial plane in CHS to measure energetic ions injected by the DNB. Combination of horizontally scannable DNB and NPA provides information on whether the energetic ions with different pitch angle are confined in the plasma or immediately lost

In order to investigate the loss cone boundary in CHS, the injection angle of the DNB has been scanned for the plasmas with a toroidal magnetic field B_t = 0.88 T and a magnetic axis position R_{ax} of 0.96 m. The target plasma is initiated and sustained by electron cyclotron resonance heating (ECRH) with a power of 220 kW for the duration of 100 msec. The beam energy (E_b) of DNB is set to be 27 keV and there are three components of beam energy: full energy (27 keV), half energy (13.5 keV) and one-third energy (9 keV). The three components of energy can be measured with two sets of energy range, 5-13 keV and 12-32 keV using different deflection voltages of the NPA. Line averaged n_e is 1×10^{19} m^{-3} and central electron temperature is 1 keV in this experiment. The heating power of DNB is small enough not to perturb these parameters.

Figure 1(a) shows the measured neutral energy spectra when the DNB is injected at tangential radius (R_T^{DNB}) of 31 cm in co-direction where the injected fast ions are expected to be confined from the orbit analysis. The NPA was scanned horizontally shot by shot from tangential radius (R_T^{NPA}) of 18 cm to 74 cm and the neutral flux is integrated over 50 msec intervals in the discharge. Each energy component of the DNB, E_b (27 keV), $E_b/2$ (13.5 keV), $E_b/3$ (9 keV) was clearly observed. As seen in Fig. 1(b), only a few CX neutrals are observed at all energy components when the DNB is injected into the loss cone region (R_T^{DNB} = 17 cm). This is because the fast ions injected to the loss cone are immediately lost before they travel to the sight line of NPA 180 degrees apart in the toroidal direction. Figure 2 shows the confinement and prompt loss domain in the space of pitch angle and major radius. The closed circles shows the NPA observation points where the neutral flux is high (>3e+15), while the open circles are the data for low neutral flux (<3e+15). The data indicated with closed circles clearly show that the fast ions injected with R_T^{DNB} of 31 cm are confined and the confined region measured is consistent with the prediction of the full orbit code. In Fig. 2, there is no data where the neutral flux is high enough for the DNB injection with R_T^{DNB} of 17 cm which is also consistent with the prediction of the orbit code. The combination of scannable DNB and NPA is a very powerful tool to study the loss cone boundary of energetic ions in CHS. The confined region in the space of pitch angle and major radius determined from measurements are consistent with that calculated with the orbit code.

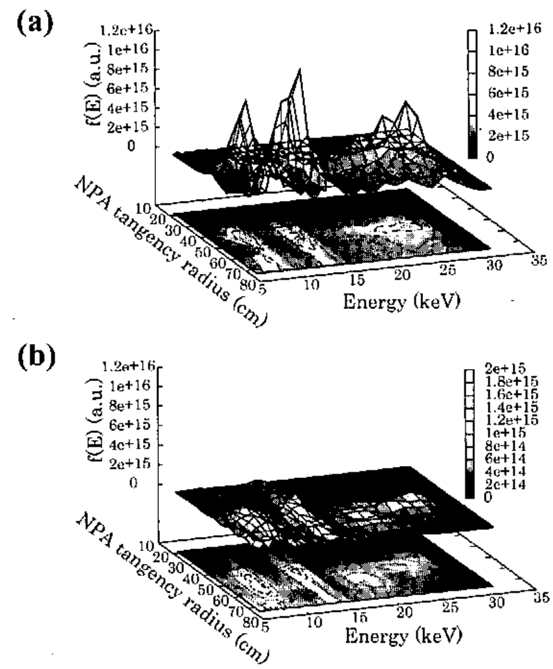

Fig. 1 Energy spectrum of neutral particles at each tangency radius of NPA for DNB injection with (a) R_T^{DNB} of 31 cm (b) R_T^{DNB} of 17 cm.

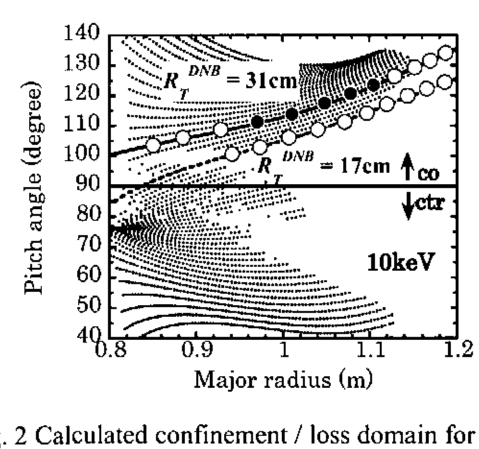

Fig. 2 Calculated confinement / loss domain for each energy component of the DNB-injected ions. The dotted area corresponds to the confinement domain. The blank area corresponds to the prompt loss domain. The solid (dashed) lines represent the beam line of DNB in R_T^{DNB} of 31 cm (17 cm). NPA observation points are plotted with circles along the beam path. Closed circles correspond to the data point where observed neutrals exceed 3e+15(a.u.).